

# **Fluid Vessel Quantity using Non-Invasive PZT Technology Flight Volume Measurements Under Zero G Analysis**

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Major: Mathematics with Engineering and Physics

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## **I. About Me**

I am a senior at the University of Central Florida. My major is Mathematics with Engineering and Physics. I plan on becoming a mechanical engineer with a focus on design and manufacturing. I would like to have a job where I not only design products, but also am involved in the manufacturing process as well. My experience at the KSC Cryogenics Test Lab has been great. They really accommodated my goals and helped me get the most out the summer. I have had the opportunity to do a variety of things that will directly impact my future job performance.

## **II. Introduction**

The purpose of the project is to perform analysis of data using the Systems Engineering Educational Discovery (SEED) program data from 2011 and 2012 Fluid Vessel Quantity using Non-Invasive PZT Technology flight volume measurements under Zero G conditions (parabolic Plane flight data). Also experimental planning and lab work for future sub-orbital experiments to use the NASA PZT technology for fluid volume measurement. Along with conducting data analysis of flight data, I also did a variety of other tasks. I provided the lab with detailed technical drawings, experimented with 3d printers, made changes to the liquid nitrogen skid schematics, and learned how to weld. I also programed microcontrollers to interact with various sensors and helped with other things going on around the lab.

## **III. Project Overview**

In a zero gravity environment, measuring the volume of propellant in a spacecraft's propellant tanks can be a very difficult task to do with a high level of accuracy because the volume of the propellant is constantly changing. As of now, there are not any technologies being used that non-invasively measure fluid volume in a zero-gravity environment. On earth you can measure fluid volume by weight or visually by some sort of gauge, but

in space you can't do either. In zero gravity, the fluid doesn't stay at the bottom of the tank; it sloshes all over the place. This makes measuring the volume very difficult to do. Last summer Rudy Werlink(my mentor) and a group of students from Carthage College went on NASA's zero g plane. The flight involved approximately 40 parabolic trajectories and each parabola provides about 20 seconds of

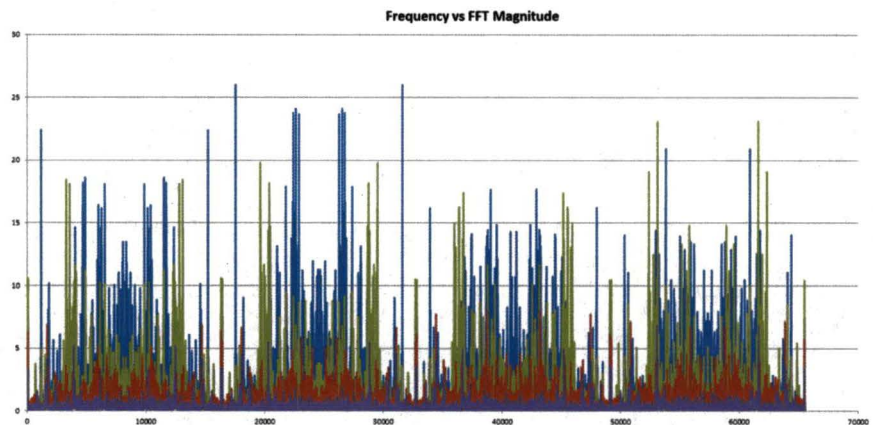


Figure 1

microgravity time. Three PZT sensors were attached to a tank. A PZT actuator was used to generate signals into mechanical pulses that vibrated the tanks. The sensors then converted the vibrations into output signal which was recorded by their data acquisition modules. Each second provided 16,384 data points from each sensor, so there was 327,680 data points from each sensor for one parabola. With 40 parabolas, this gives me 13,107,200 signals to do FFT analysis on. FFT analysis is widely used in the vibration and sound industries. A fast Fourier transform (FFT)

is an algorithm that transforms a function of time into a function of frequency. Doing FFT analysis on the flight data gives a column of complex numbers. Taking the modulus of those numbers gives the FFT magnitude. The FFT frequency depends on the analog to digital converter resolution. To get the ADC resolution, divide half of the

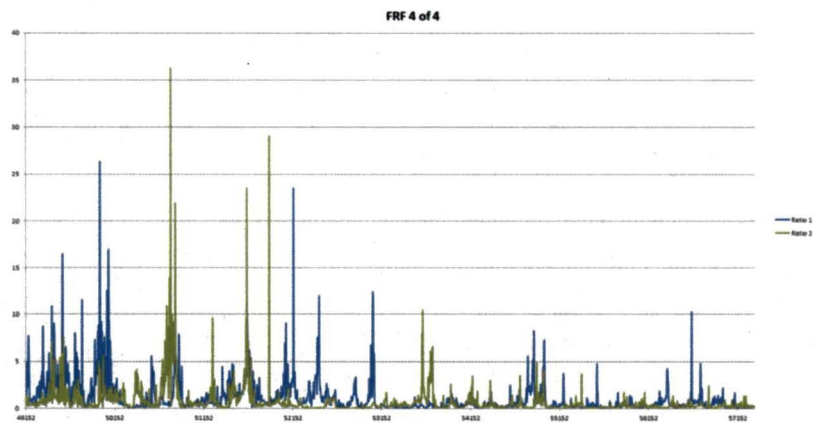


Figure 2

sampling rate by half of the sample size. After doing FFT analysis of all the sensors, I averaged them to produce figure 1. Similar graphs are made for each second of each parabola. FFT analysis is done on the input signals as well as the output. Then dividing the output FFT magnitude by the input FFT magnitude gives the frequency

response function (FRF). Figure 2 shows the FRF of 2 PZT sensors. The FRF is essentially just the mathematical relationship between the input and output of the system.

#### IV. Welding

As soon as I discovered that there was a weld shop at the other end of the cryogenics test lab I knew that I wanted to spend some time over there. I have always appreciated a nice weld and wanted to learn from the professionals. Everyone at the shop was very open to teaching me different type of welds and techniques. At the weld shop, they do shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW). In SMAW, a current is used to produce an arc between the product being welded and the rod. The rod is covered with a flux that keeps the oxidation of the weld area down by producing carbon dioxide when it is welded. In GMAW, also known as MIG welding, the process uses a continuous wire feed instead of a rod. The wire doesn't need flux because a gas or gas mixture is used to protect the weld from contaminants. You can use a MIG welder without gas, but you will need wire that has a flux core to protect from contamination. In GTAW, also known as TIG welding, the welding process involves using a tungsten electrode, a gas mixture, and material you choose to weld with. TIG welding requires the most skill out of all the types of welds.

#### V. 3D Printing

3d printing has been around for some time now, but it is just now receiving the much needed attention it deserves. Since the expiration of the patents on this technology, there has been a huge boom of 3d printers for regular consumers. For years only big companies could buy them, but now you can buy a home 3d printer for around \$1000. All the printer needs is an .stl file, which is a standard 3d drawing format. Most 3d design software packages can export to .stl format. Even if you don't know how to draw 3d models on the computer, there are thousands of free models you can download online. I really feel that 3d printing is going to be very affordable soon and big part of our futures. Rapid prototyping will lead to great inventions that can't be assembled any other way. I had the chance to actually see few different types in action and actually use one of them to print out 3d models.

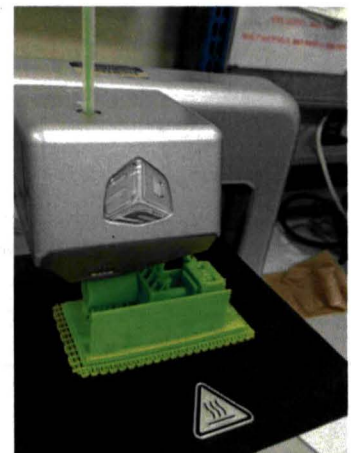


Figure 3



## VI. Liquid Nitrogen Skid Schematics

If you were to walk to the back of the cryogenics test lab, you would see thousands of little pipes intertwined like a brain. That's just what it is. It's basically the brain and heart of the cryogenics test lab. It supplies liquid nitrogen all throughout the lab. With a variety of sensors it can detect where leaks are happening and the flow through the entire skid. The liquid nitrogen skid communicates with 15 psi bursts that express which control valves to open and close. As you could imagine, the schematic for the skid is just as complex. Here at the lab, they are continuously updating and adding new pipelines and valves to the skid. I was in charge of updating the changes to the schematics and ensuring that what was already installed was correct. It was a much more difficult task than just adding to the drawings. I had to trace the pipelines back to where they came from. This involved using bright orange tape so I wouldn't lose my tracks. This is when I realized just how complex the system is. I had to crawl in tight spaces and follow a pipe that could split into 4 pipelines and continue to split. After following all the pipes until I found where they came from, only then could I actually make changes to the schematics.

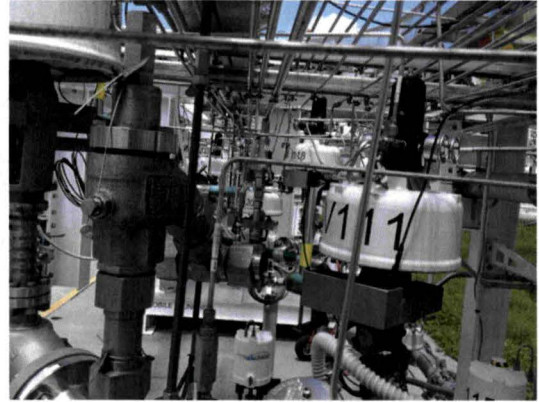


Figure 4

## VII. Programming Microcontrollers

Over the summer, I learned a great deal about microcontrollers and how to program them. Microcontrollers are small integrated circuit chips that can be programmed to interact with a wide variety of sensors, motors, and other electrical components. I like them so much I bought two of my own and brought them to the lab. The specific microcontrollers that I bought are called Arduinos. I chose this chip because it is programmed with C and C++ programming language. Both of which I am very familiar with. I used the board to interact with a variety of sensors at the lab. I was particularly interested in the PZT sensors and how they detect vibrations and stresses. I used the second arduino board that I had in conjunction with a moisture sensor to make an automatic watering system for my plants. I

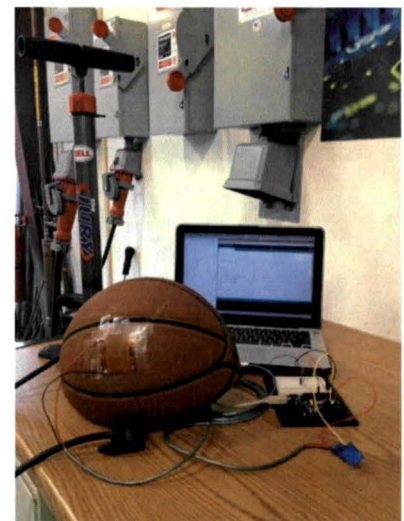


Figure 5

programmed it to take readings from the moisture sensor and if the reading fell below a certain point, it would charge a transistor that triggers a relay which opens the solenoid valve to the misters I made.

### **VIII. Other**

Over the duration of my internship, I was able to be a part of various experiments as well as conduct a few of my own. We used thermocouples to see what the temperature changes of the inside of marshmallows, hotdogs, and pork roast after submerging them in liquid nitrogen. I cut the pork roast into the shape of fingers and a palm. And then we inserted thermocouples at different distances from the surface. The outermost layer froze within 3 seconds. The center of the pork froze in 6 minutes and 30 seconds. Figure 6 shows a piece of pork with thermocouples submerged in liquid nitrogen. I also did a few experiments with the arduino and a PZT sensor. First, I programmed the board to light different LEDs depending on how much pressure you put on the sensor. Then I secured a PZT sensor to a basketball in Figure 5 and pumped it up to different pressures. At each increment of 5 psi, I struck the side of the ball with a metal rod. Performing FFT analysis on the data yielded interesting results. Just as they used the PZT sensors to measure fluid volume in the tanks, I was able to see a relationship between the frequency responses at different pressures. Each increment of 5 psi would shift the frequency of the graph to the right.



**Figure 6**

### **IX. Conclusion**

Overall, I had a great experience. I had the pleasure of working with a handful of brilliant people. I learned new skills and got to see how things work at the Cryogenics Test Laboratory. I would like to thank Rudy Werlink and everyone involved that made this possible. I would also like to thank everyone at the Cryogenics Test Lab for making my summer so memorable.